

DESKTOP CARTOGRAPHIC AUGMENTED REALITY: 3D MAPPING AND INVERSE PHOTOGRAMMETRY IN CONVERGENCE

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Introduction

The issue of augmented reality (AR) is only recently beginning to be investigated within the broader context of Cartographic / Geographic Visualization. AR refers to the combination of real and virtual environments (VE), for achieving more realistic representations. The present paper describes a fast and cheap method for creating AR visualizations of urban scenes in a desktop environment.

The mix of VE and the “real world” that AR implies, requires in the first place the proper combination of a model of reality (e.g. a 3D model comprising the VE) and an image / images of the real environment (e.g. photos or/and frames of a video sequence). In the simplest case these images will have to be attached/draped over the surfaces of the 3D model (e.g. buildings’ facades, a DTM etc.), thus creating a realistic impression. A more interesting –and computationally more complex- case is when the “real world” images comprise the environment within which the 3D model is located, i.e. they constitute the model’s surroundings / background. Since the two items (i.e. 3D model and images of reality) are, in practice, acquired separately, their proper combination refers to applying the right perspective to the model, so that it will fit into the perspective of the real scene.

It is at this point that the notion of Inverse Photogrammetry becomes particularly useful, since it can help carry out this combination in practice. Inverse Photogrammetry, as the term implies, is an inverse operation of the custom photogrammetric procedure. While in the latter the purpose is to reconstruct the 3D geometry of an object based on perspective views of it (recorded on photos), the purpose of Inverse Photogrammetry is to create a perspective view of an object when its geometry is known in 3D space. Inverse Photogrammetry has been developed and used primarily as a visualization tool, for instance for viewing projected developments or past (historical) situations within a currently existing environment. Since no strict metric needs are of primary concern, fast and cheap methods for both the data to be gathered and the photogrammetric processing –leading to the final visualization product- are favorable.

An application of the above principles is given in the paper: it concerns a location within the city of Thessaloniki, in Greece. In order to meet the requirements for fast production and low cost, video recording has been used for data input and user friendly software for data processing and display.

Augmented Reality

Augmented Reality is a growing area within the broader field of Virtual Reality (VR). The worlds used in virtual environments try to duplicate the real world, which, however, provides a wealth of information and becomes, therefore, difficult to duplicate. VR worlds are either simplistic or they require an expensive system for more realistic representations (e.g. a flight simulator). Augmented Reality generates a composite view: it is a combination of a real scene viewed by the user and of a virtual scene generated by the computer (Vallino, 1998). The objects of the real scene (i.e. the real world objects) can be displayed by simply scanning, transmitting and reproducing image data, as is the case with ordinary video displays, where there is no need for the display system to “know” anything about the objects (Drascic and Milgram, 1996). On the other end of the Reality-Virtuality Continuum, virtual images can only be produced (by a computer), if there is a model available for the objects being drawn.

The concept of the Reality–Virtuality Continuum (Drascic and Milgram, op.cit.) facilitates understanding the whole spectrum of the combined use of real and virtual media for representing the world. At the one end of the spectrum, *Reality* refers to the situation where a scene is observed via a direct view (DV) or via (stereo) video (SV). At the opposite end of the spectrum, *Virtual Reality* (VR) refers to (stereo) graphical (SG) models of objects, with known geometry in 3D space. In-between lies what is known as *Mixed Reality* (MR), which refers to the class of displays where there is some combination of the previous two (i.e. *Reality* and *Virtual Reality*). Augmented Reality lies near the real world end of the Mixed Reality line: the predominate perception is the real world, augmented by computer generated data. Milgram (op.cit.) used also the term “Augmented Virtuality” (AV) to identify systems which are mostly virtual (i.e. computer models) with some real world imagery added, such as texture mapping onto virtual objects. This, however, is a distinction that is anticipated to fade as the technology improves and the virtual elements in the scene become less distinguishable from the real ones. (Vallino, op.cit.)

Examples of AR applications are increasing in the scientific areas dealing with Geographic Information (Cartography, Surveying, Photogrammetry etc). Such applications concern tasks of Computer Aided Engineering Design, Hazardous Mapping (see e.g. Chapman et al., 1999, Hall, 2000). Other application areas include medical, entertainment and education, defense, robotics etc. Cartographic issues related to AR have only recently begun to be investigated within the broader context of Cartographic / Geographic Visualization.

A key point in AR is the correct registration of the computer-generated models (i.e. the virtual objects) with the real world, in all dimensions. This results in maintenance of the correct registration while the user moves about in the real environment. If there are errors in this registration the user will not be able to perceive the real and virtual images as fused. The need to calculate the exact position of the model within the real scene introduces some photogrammetric concepts, given in more detail in the next section.

Another important issue for AR applications is the display technology used. The simplest available is monitor-based viewing of the augmented scene. With this technology the user has rather limited feeling of being immersed in the environment created by the display. To increase the sense of presence, more sophisticated -but also more expensive- display technologies are needed, such as head-mounted displays (HMD). These have been widely used in virtual reality systems and can be distinguished in two types: video see through and optical see-through (Vallino, op.cit.).

Inverse Photogrammetry

In order to fuse virtual objects and real scenes in a common AR environment, techniques familiar from photogrammetric applications are used; Inverse Photogrammetry, in particular offers new possibilities when applied in a virtual environment. Inverse Photogrammetry, as the term implies, is an inverse operation of the custom photogrammetric procedure. While in the latter the purpose is to reconstruct the geometry of an object based on perspective views of this object (recorded on photographs), the purpose of Inverse Photogrammetry is to recreate a perspective view of an object when its geometry is known in 3D space. This is particularly useful in architectural or civil engineering projects, where a planned construction, such as a new building, can be incorporated in existing photographs of the site of the project, on the basis of its planned position within the area. In this way the new situation can be visualized before its realization and the result can be examined from aesthetic, morphological etc. point of view.

The procedure of Inverse Photogrammetry involves plotting the planned construction on a photographic perspective taken from a certain point of view in a certain direction (Carbonnell, 1989). This can be done if one knows the (X, Y, Z) coordinates of characteristic points of the future construction, the (X, Y, Z) coordinates of the point of view, the direction of the camera axis and the camera constant. Applying the collinearity condition, the image coordinates of the respective construction points can be calculated and plotted on the photo. The typical steps of such applications, which have been used for long in Photogrammetry, are (Yacoumelos, 1970):

- Acquisition of the 3D geometry of the new construction.
- Photographing the surrounding area from suitable viewpoints.
- Construction of the 3D perspective of the object.
- Incorporation of the object in the photograph(s) or even in a stereo pair of photographs.
- Examination (in monoscopic or stereoscopic viewing) of the result.

A similar technique known as the “reverse projection” technique has also been used in (non-topographic) photogrammetric applications, such as accident scene reconstruction (see, for example, Whitnall and Moffitt, 1989)

All the previous have traditionally been applied -by photomontage (i.e. photo mounting)- on photographs taken from a certain perspective. This means that in order to be able to examine a future situation from various viewpoints within its surrounding environment several shots have to be taken and the inverse photogrammetric technique has to be applied repetitively, i.e. for each shot. Furthermore, in order to be able to have an overview of a project within its broader geographic area, airphotographs should be actually available.

By using a virtual graphics environment (such as a CAD environment), not only for scene reconstruction, but also for viewing results, alternative solutions to such limitations of the traditional method are possible. In a CAD environment, possibilities such as the examination of the scene from any desired point of view, the creation of walk- and fly-throughs etc. are common practice. By adding color, texture and shading to both the existing and the new constructions, photorealistic visualizations are possible, which can give a photographic impression to the product. Furthermore, in such an environment the concept of Inverse Photogrammetry can be expanded by the possibility to reconstruct the real environment through placing and registering together the model and images of the real scene. In this way the 3D model is augmented by recorded scenes of the reality surrounding it (Koussoulakou et al., 1999).

An application in the city of Thessaloniki

The present application is about placing a new construction in an existing area of a city (Thessaloniki) and visualizing the new situation. Given that usually the products of Inverse Photogrammetry are a means for satisfying visual inspection and overview purposes rather than strict metric needs, it would be meaningful to generate the required product as efficiently as possible. Favorable, therefore, are fast and cheap methods, with the minimum possible requirements for the data to be gathered, the photogrammetric processing to be followed and the display technology to be used. On the other hand the final product should give the impression of realism as much as possible; it should also be available in a suitable environment for the users to examine. The basic steps followed are:

- **Acquisition of the 3D geometry of the new construction**
- **Recording the surrounding area**

A video camera is used to record the area, since it offers a fast, flexible and cheap way of data input. More specifically, recordings are made from a number of viewpoints, so that all the existing elements in the area can be reconstructed later (e.g. buildings and their facades, but also the surrounding scene).

- **Creation of the 3D environment**

This includes the 3D virtual objects, as well as the surrounding scenes (in the form of 2D images attached on 3D surfaces, for depicting the more distant environment as a background). These are fused, based on camera position and settings.

- **Examination of the result**

The display technology used is -for efficiency and cost reasons already mentioned- the simplest available i.e. desktop (or monitor-based) viewing of the AR scene. By making use of -basically- a CAD environment a variety of ways for visualizing the result is available. These include: changing the viewpoint of observation for examination of the new project from any point of view, applying photorealism, generation of stereoscopic views for a more realistic sense of depth of the observed scene. Furthermore it is possible to simulate photographic shots within the virtual environment of the 3D file, by setting and adjusting a virtual camera, which can be positioned and oriented in any manner required within the space of the 3D file. Depending on the settings, the respective portion of the file is displayed in perspective projection. Various "lenses" (i.e. input parameters for focal length and angle) are also available to modify the resulting image.

The steps outlined above were followed in an application that was carried out for a spot in the city of Thessaloniki. An area in the new sea promenade of the city, a (fictional) extension of the promenade into the sea and the construction of a building for general public use (e.g. recreation, cultural etc) were chosen as a test case.

A CAD software program (*Microstation* by *Bentley Systems Inc.*) was used for 3D scene reconstruction and visualization of the results. Since no 3D data file of the area was directly available this had to be constructed, mainly on the basis of the video recording and a topographic plan of the area. Data collection was carried out by means of video recording of the area. A *CCD-V600E Video Hi8* handycam video camera/recorder (camcorder) was used. Apart from the already mentioned low cost and flexibility of video recording, an immediate advantage is the presence of overlap in the video images. This can help overcome the unavoidable difficulty of the limited coverage in images, especially when recording from short distances (e.g. because of narrow streets). The video recording was downloaded in a number of digital video files and images, with the help of the software package *Adobe Premiere LE*.

For the planimetry of the area a topographic plan (scale 1:500) available from the city Municipality was used. The 3D geometry of the area can then be generated from the 2D topographic plan and the suitable still snapshots (i.e. still video images). An easy to use

software program (*3D Builder* by *3D Construction Company*) was used for this purpose. *3D Builder* generates models from images and is designed for generic use. Its calculations are based on the perspective characteristics of the central projection (vanishing points). Therefore no need for control points is necessary. After the 3D model was generated the facades of the buildings were attached on the respective surfaces, for a more realistic impression. These facades had, of course, to be rectified first. The photogrammetric rectifications were carried out with the help of the software package *I/RASC* (*Intergraph Corp*). Finally, the CAD environment was used for the visualization of results. An overview of the generated file, showing the existing and the planned area in a 3D model is given in Fig. 1.

For combining the 3D model (the VE) with the video frames depicting the real world, two visualization possibilities are implemented:

1. The generation of AR video sequences with predefined view-paths. This is achieved by combining the 3D model with the original video frames and creating new videos. In Fig. 2 an output of the above procedure is shown through some frames of a video sequence showing the spot where the new construction is to be located. After frames and 3D model are fused, a new video sequence is created. In this way, a dynamic overview of the area with the new situation can be displayed.

2. The interactive manipulation of paths for walking- and flying-through the area of the model, having realistic backgrounds. These backgrounds are obtained from processing of video sequences (or even terrestrial photos, taken with a non-metric camera). A complete picture of the surrounding scene is built by attaching the background on 3D surfaces (cylindrical and spherical) surrounding the area. Although a more demanding case, the latter offers the advantage of moving through realistic scenery, instead of the ready-made sky-like backgrounds usually utilized in similar applications. Views of this type are given in Figures 3 and 4.

Conclusions

The attempt to produce a cartographic desktop AR environment, having in mind the objectives stated previously in the paper, has certain advantages; some limitations are, however, unavoidable. Both positive and negative aspects can be summarized in terms of *Data capture*, *Equipment and Tools*, and *Presentation of results*.

Most of the difficulties encountered are related to limitations and obstacles present during *Data capture*. Narrow streets, for instance, seem to be a major obstacle when recording buildings (A photomosaic from overlapping images can offer a solution, but increases the amount of work. Other solutions, such as the use of wide-angle lenses, are assumed not available for a common video camcorder). Other commonly encountered obstacles include lampposts, columns, tree-trunks and foliage, parked cars etc. Some of these are impossible to eliminate from images; often, therefore, they are recorded as part of building facades.

Both *Equipment* for data capture (video) and *Tools* for data processing and display are easy to use, flexible and low cost. Although a variety of software tools was used for the step by step processing of the data, these are all general purpose, user-friendly, inexpensive and nowadays commonly available.

The CAD environment used for the presentation -chosen for pragmatic reasons mentioned previously (the need for fast and cheap production and equipment)- is the simplest that can be used for AR purposes, as already mentioned, its most serious weakness being the lack of immersion. This can be overcome, to a degree, by the production and viewing of stereo images. The result has many options for overview of a project within a broader geographic area,

although the data collection is done terrestrially. Furthermore realism is simulated to a satisfactory degree and the existing photorealistic effects can be manipulated at will (e.g. solar study, view of vegetation in various seasons etc.). Another advantage is the possibility offered by the CAD environment to reconstruct traditional inverse photogrammetric products (photo mountings, simulation of photographic shots) and even expand them through new products (i.e. video sequences with the new situation viewed in a realistic background).

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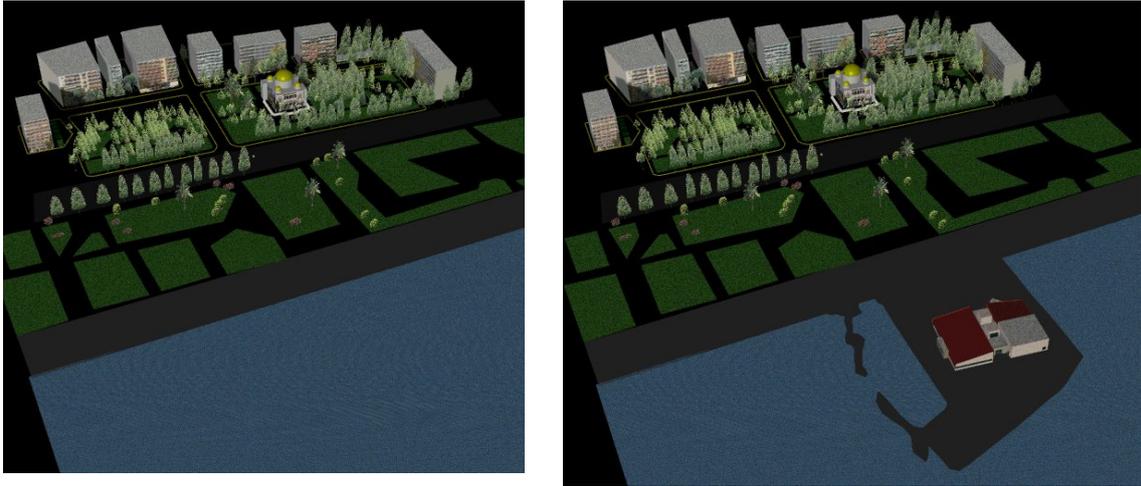


Figure 1. A 3D model of the existing area (left) and of the project planned (right).



Figure 2. Mixed Reality for viewing a projected development: the 3D file of a new building is inserted in the video sequence displaying the existing situation. Above: frames from a video showing the current status. Below: video fused with the 3D display.

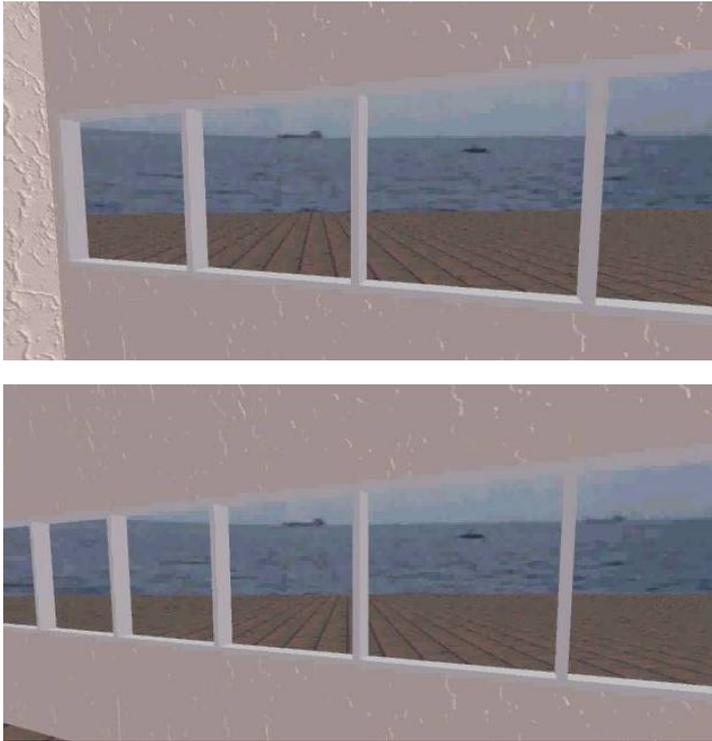


Figure 3.

Combination of a real scene with a 3D model: a simulation of the view to the sea from inside the new building. The sea view at the background is obtained from a video sequence and registered to the scene; the building is part of the 3D model of the area.

Figure 4. Combination of a real scene with a 3D model. Distant views are registered to the 3D virtual environment, for serving as realistic backgrounds.

